BETTER CROPS WITH PLANT FOOD

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IN THIS ISSUE

Aglime Benefits

BETTER CROPS
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Our Cover: Spreading aglime — an important management practice for crop production.
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CONTENTS

Spring-Applied Aglime Can Provide Immediate Soybean Response

By C.S. Snyder, J.H. Muir and G.M. Lessman

Maintaining proper soil pH is the foundation of a good soil fertility and nutrient management program. Agricultural limestone (aglime) use where needed remains a good investment and is a critical best management practice (BMP) in crop production. With increased nitrogen (N) use for rotational crops, larger amounts of crop residues associated with reduced tillage practices, and higher yields, soil acidity and aglime needs should be monitored through soil testing.

> Research in the Midsouth shows that application of good quality agricultural limestone can have beneficial effects on soybean yields even when applied immediately prior to planting.

Many farmers believe that if they don't apply aglime at least six months ahead of the crop, they won't see a benefit. While it is best to apply aglime and incorporate it well in advance of the targeted crop, university research in the Midsouth U.S. indicates good crop responses can be experienced when it is applied as late as planting time.

Liming Materials

High quality aglime has a calcium carbonate equivalence (purity) of 90 percent or more. It also has a desirable distribution of effective particle sizes. In quality aglime, 90 percent of the particles pass a 10 mesh sieve, 40 percent pass a 60 mesh sieve, and 25 percent pass a 100 mesh sieve. Each ton may contain 500 lb or more of fine particles that begin to neutralize soil acidity immediately. Larger particles (60 to 100 mesh) react over several months. Even larger particles within the range of 10 to 60 mesh may require a year or longer to neutralize soil acidity.

Other liming materials include fluid or suspension lime and pelletized lime. Fluid lime is a mixture of fine lime (often 200 mesh or finer), water, and a suspending agent in about a 50:50 mix of water and fine lime particles. Pelletized lime is fertilizer granule-sized pellets made from relatively fine limestone particles. As much as 50 to 70 percent of the aglime used to make the pellets is 100 mesh or finer. The final pellet size is comparable to fertilizers so that pelletized lime may be spread by conventional fertilizer spreaders.

In central Arkansas, aglime costs range from \$12 to \$24 per ton spread. The price of pelletized lime often ranges from \$90 to over \$100 per ton spread. Fluid or suspension lime may be priced near \$30 per ton spread. This equates to about \$60 per ton of dry, high quality aglime. Transportation distance is one of the major factors affecting the price of the various sources.

Comparison of Liming Materials

Applications of 250 to 300 lb/A of pelletized lime have been suggested as a substitute for one ton of aglime. At a 250 to 300 lb/A rate of pelletized lime, costs might range from \$11 to \$15 per acre. Lower rates are normally intended only to maintain soil pH at present levels, or to prevent further pH decline.

Arkansas research with aglime and pelletized lime was recently conducted on a Loring silt loam soil with a 3 to 8 percent slope and a 4.8 water pH, using no-till soybeans (nonirrigated) doublecropped after wheat. Liming materials were applied in early July and a disk was used to very lightly scratch the soil surface to help ensure the materials stayed in place on the slope. The results indicate that it would take about 500 to 700 lb/A of pelletized lime to equal the soil reaction and soybean yield response from one ton of good quality aglime (**Figure 1**). Both were effective in increasing no-till soybean yields even with minimal incorporation.

Similar work with soil-incorporated fine lime (100 mesh) and aglime has been conducted in Tennessee. The fine lime material was suspended in water and applied as fluid lime. **Figure 2** illustrates the pH response measured within 100 days of application. Little change in soil pH was noted until lime rates were 1,000 lb/A or greater.

First-year soybean lime responses in Tennessee (**Figure 3**) were about 6 bu/A and peaked at the recommended rate of 2 tons/A of aglime. A rate of about 500 lb/A of fine lime was required to produce a significant yield response. Responses over a five-year period (**Figure 4**) of continued aglime application rose to about 14 bu/A with a net application of 4 tons/A.

Summing up, here are several guidelines.

• Recommended rates of good quality aglime can significantly change soil pH within 100 days of application, and frequently within 45 to 60 days, if properly incorporated.

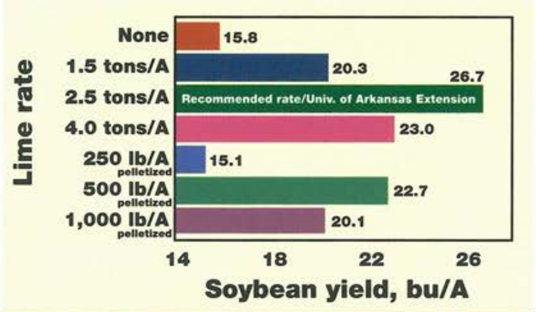

FIGURE 1. Doublecropped soybean responses to aglime and pelletized lime. Source: Muir et al., Arkansas

• Low rates (250 lb/A) of pelletized lime are not an agronomic or economic substitute for one ton of good quality aglime.

• It may take 1,000 lb/A or more of fluid lime (50 percent water: 50 percent 100 to 200 mesh fine limestone) or 500 to 900 lb/A of pelletized lime to provide the same short-term response as one ton of good quality aglime.

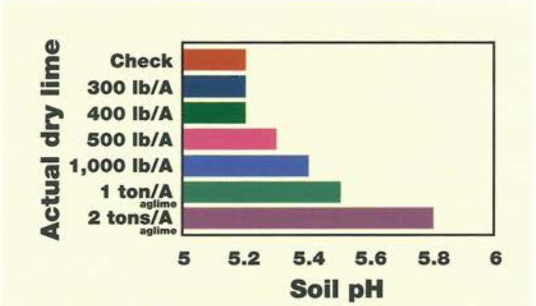

FIGURE 2. Soil pH 100 days after lime application. Source: Lessman, Tennessee

• Use of low rates of pelletized lime or fluid lime will probably result in a need to re-lime sooner than if recommended rates of aglime are used.

• If pelletized lime is used, it should be allowed to "melt-down" with rain or irrigation before soil incorporation. Subsurface banding of lime has failed to show any practical yield benefits compared to broadcast, soil-incorporated aglime at recommended rates.

Recommended rates of aglime applied ahead of soybean planting have resulted in yield increases of 4 to 10 bu/A or more the first year, and also for the next three to seven years. One of the major benefits from liming is an increase in the availability of soil molybdenum (Mo) when the soil pH is increased. If the decision is made not to lime acid soybean land, then a Mo seed treatment should be considered. When soils are strongly acidic and Mo is not used, response to applied phosphorus (P) and potassium (K) may be limited. Maximum efficiency in nutrient uptake by plants will not be realized unless the root environment is maintained in the desirable pH range, usually 5.8 to 6.5 for southern soybeans. BC

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SOYBEAN DEVELOPMENT suffered in this field area with soil pH of 4.1. Manganese toxicity also affected the plants, with "crinkle leaf" symptoms.

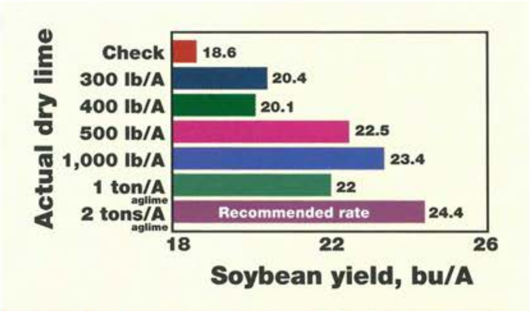

FIGURE 3. Aglime effects on soybean yields – first year.
Source: Lessman, Tennessee

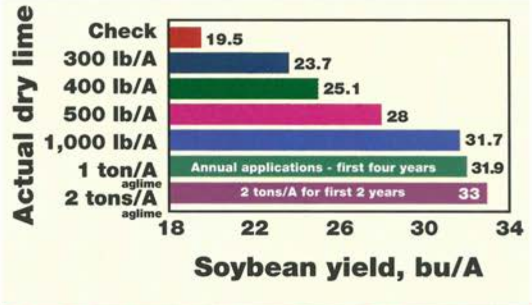

FIGURE 4. Annual aglime application effects on soybean yields – five-year average.
Source: Lessman, Tennessee

VIRGINIA

Short-term Soil Chemical and Crop Yield Responses to Aglime Applications

By M.M. Alley

Crop yields are reduced on acid soils due to toxic concentrations of aluminum (Al) and, in some soils, manganese (Mn). The availability of applied and residual soil phosphorus (P) in mineral soils is maximized when soil pH levels are between 6.0 and 6.5, as is the retention and availability of applied potassium (K).

For legume crops, the nitrogen (N) fixing capacity of Rhizobia bacteria is maximized at pH levels between 6.0 and 7.0. Rhizobia need high levels of available calcium (Ca) and magnesium (Mg), as well as adequate supplies of molybdenum (Mo), the only micronutrient that increases in availability as soil pH increases. Moreover, other soil organisms that decompose organic matter and contribute to the general health of soils are most active at soil pH levels of 6.0 to 7.0. Finally, many herbicides lose effectiveness as soils become acid.

> Recommendations for aglime use generally call for application at least 2 to 6 months prior to planting due to the slow rate of soil-lime reaction. Virginia studies show that soil chemical properties change rapidly and that crop yields increase with aglime applications made immediately prior to planting on acid soils.

Recommendations for aglime use generally call for an application at least 2 to 6 months prior to planting due to the supposedly slow rate of soil-limestone reaction. In practice, much aglime is applied immediately prior to planting because of soil and crop conditions, or the application is delayed because of the belief that

TABLE 1. Liming affects soil pH, exchangeable soil Ca and Mg. It also decreases exchangeable Al and lowers Al saturation of the soil's exchange complex.

	Goldsboro sandy loam					Pacolet sandy clay loam				
		Exchangeable					Exchangeable			
Lime rate, tons/A	pH	Ca	Mg meq/100 g	Al	Al sat.[1], %	pH	Ca	Mg meq/100 g	Al	Al sat.[1], %
0.0	4.1	0.21	0.08	1.66	76	5.3	1.94	0.89	0.27	8
0.5	4.6	0.38	0.24	1.15	56	–	–	–	–	–
1.0	4.6	0.53	0.40	0.56	33	5.9	2.06	1.01	0.04	1
2.0	5.0	0.74	0.54	0.32	18	5.9	2.30	1.12	0.02	1
3.0	–	–	–	–	–	6.2	2.40	1.19	0.02	1
4.0	5.2	1.01	0.78	0.04	2	6.2	2.40	1.20	<0.01	<1
6.0	5.5	1.20	0.95	0.02	1	6.5	2.80	1.33	<0.01	<1
8.0	–	–	–	–	–	6.4	2.80	1.40	<0.01	<1

Sampled 16 weeks after liming. Virginia

[1]**Percent Al saturation** = $\frac{\text{Exchangeable Al}}{\text{Exch. Ca + Exch. Mg + Exch. K + Exch. Al}} \times 100$

little benefit will be obtained by the initial crop. This article reports on studies that were conducted to quantify initial crop yield benefits as well as soil chemical changes that occur soon after aglime applications.

TABLE 2. Good quality aglime soil incorporated immediately prior to planting can significantly increase crop yields.

Lime rate, tons/A	Goldsboro soil Corn yield, bu/A	Pacolet soil Barley yield, bu/A	Frederick soil Alfalfa yield, lb/A
0.0	21	49	303
0.5	87	–	–
1.0	105	61	1,229
2.0	104	56	1,674
3.0	–	56	1,817
4.0	110	65	2,191
6.0	121	60	2,262
8.0	–	59	2,369

Virginia

Virginia Studies

Three acid soils on growers' farms were used for these studies: a Goldsboro sandy loam (Coastal Plain region), a Pacolet sandy clay loam (Piedmont region), and a Frederick silt loam (Valley region). A commercially-available dolomitic aglime, containing 54 percent calcium carbonate and 43 percent magnesium carbonate, was utilized for these studies. The particle size distribution of this aglime was 88, 60 and 50 percent passing 20, 60 and 100 mesh sieves, respectively. The aglime was applied at various rates and incorporated with tillage immediately prior to planting each crop. Corn was planted on the Goldsboro soil, barley on the Pacolet, and alfalfa on the Frederick.

Results

Lime treatments increased surface soil pH at all locations within 16 weeks of application (**Table 1**), and other observations showed measurable increases in soil pH two weeks after aglime application. Exchangeable Ca and Mg levels were increased and exchangeable Al levels decreased with aglime application. These effects are reasonable responses because the aglime particles passing a 100 mesh sieve can be expected to be almost immediately reactive in acid soils.

Corn, barley and alfalfa yields were all increased with aglime applications (**Table 2**). Regression analyses indicated that corn yield increases were strongly associated with reductions in exchangeable Al levels, while first-cutting alfalfa yields were related to increases in soil pH and exchangeable Ca and decreases in exchangeable Al. Barley responses to limestone on the Pacolet soil were limited by severe winter-kill which resulted in variable yield data.

Summary

Soil pH and exchangeable soil Ca and Mg increased, and exchangeable Al levels decreased during the 16-week

(continued on page 9)

GOOD QUALITY aglime can have immediate effects on crop growth and yield. Corn plants in the foreground are growing on an unlimed area. Liming produced the growth difference shown by plants in background.

WASHINGTON

Time to Re-Apply Lime to Orchards in Washington?

By Timothy J. Smith

The Problem

In the mid-1980s, fruit growers of north central Washington realized that soil pH had dropped to dangerously low levels in a band about 10 feet wide and 3 feet deep under tree rows. Many growers tested blocks in their orchards and applied 2 to 4 tons/A of high quality aglime where pH was found to be too low. Soils are primarily sandy loam in texture, ranging from sand to loam.

Liming orchards in north central Washington often visibly improves tree growth within a year of application...even when aglime is surface applied.

The Solution

In orchards where aglime was spread, tree growth often visibly improved within a year of application. Nitrogen (N) fertilization was halted or greatly cut back for a few seasons to control tree vigor. Symptoms of manganese (Mn) toxicity (bark measles), which is common on spur-type Red Delicious apples growing in low pH soil, was reduced or totally cured. Leaf size and color were also improved.

All of these positive effects occurred despite the fact that aglime was surface applied, although incorporation is recommended for most rapid benefit. Aglime dissolves very slowly in water and may require many years to move into the soil by irrigation and winter precipitation.

AGLIME application in apple orchards of Washington state can offer several benefits to improve production.

Local studies carried out in the 1970s showed that orchard soil pH would eventually be affected by aglime application, even two or three feet deep. The top foot of soil, however, was most rapidly affected and its pH was increased the most. For example, pH of the top foot in one experiment went from 4.5 to 6.5 after eight years, while pH in the second foot increased from 5 to 6.

The rapid tree response common in treated orchards apparently happens when aglime raises the soil pH in only the top few inches. There is a high level of tree root activity in the surface 6 inches. That means trees can take advantage of the benefits of topdressed aglime, such as enhanced nutrient release, before much pH correction has taken place in the upper 6 to 12 inches. Although improving the pH throughout the soil profile will have a less dramatic effect and will take decades to accomplish, it is necessary for long-term tree health.

At the time the 1980s liming boom took place, university and Extension personnel advised growers that surface applied aglime worked slowly and that high rates were no more effective than 2 to 4 tons/A. The recommended approach was to apply 2 tons, wait a couple of years, apply 2 more tons, then give the aglime a number of years to become fully effective.

About 6 to 10 years have passed since liming was emphasized in area orchards, and it may be time for assessment and possible re-treatment. Most orchards have built up a "lime debt" of at least 8 to 10 tons/A over the past 20 years, so we will need to continue coming back to this issue for another decade or so before we can return to a maintenance mode.

Soil pH can be sampled any time the soil is not frozen. Samples should be taken from the top 6 inches, 6 to 12 inches, and 12 to 24 inches, taking care to prevent cross contamination between the samples (e.g., sluffing of surface soil into the sampling hole may result in an artificially high pH for the deeper samples). Assessing pH trends at the three depths will indicate the progress of the aglime application. If the pH of the surface 6 inches is well above 7.0, then there is still free aglime present and applying more will not necessarily speed the correction of pH at lower depths. On the other hand, if the surface pH is near or below 7.0, and the second foot is 6.0 or less, the orchard is probably ready for more lime.

Summary

The positive effect of proper soil pH for fruit production is too important to overlook. Trees pick up important nutrients...especially N, calcium (Ca) and phosphorus (P)...much more efficiently when pH is above 6.0. Since considerable time and money can be spent improving the nutrient status of trees by applying various fertilizer products, it makes sense to maximize their potential benefit with a proper liming program. BC

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Responses to Aglime... *continued from page 7*

period following dolomitic aglime application to three acid soils typical of the mid-Atlantic region. More importantly, crop yields were increased, and these increases were directly associated with the changes in soil chemical properties from aglime applications made at planting. Data clearly indicate that crops planted into acid soils do respond immediately to aglime applications. Aglime applications should never be postponed because of the belief that aglime reaction will be slow. Aglime with a relatively high calcium carbonate equivalency (85 percent or greater) and a significant portion (30 percent or more) of particles passing a 100 mesh sieve, will react immediately with soil acidity and increase crop yields.

Finally, one of the most difficult situations for a grower is to suffer yield losses due to acid soils, and then face the prospect of a large cost per acre for liming. Regular soil testing and aglime use must be a part of the farm management program each year so that costs are not too great in any one year, and soil pH values do not fall to levels that result in crop yield reductions. Liming acid soils is the foundation for an efficient crop production program. BC

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GEORGIA

Aglime: A Low-Cost Alternative Source of Calcium for Peanuts

By Gary J. Gascho

Calcium is often considered the essential element most commonly deficient for peanuts in noncalcareous soils. The need for Ca in peanuts is exceptionally high and its uptake by the peanut plant is unique. The fruit develops by absorbing nutrients directly from the soil as opposed to nutrients being absorbed by roots, transported to shoots and back to the fruit. It is this unique aspect that has required much research and which guides the application of Ca for greatest yield, quality and seed germination.

> Farmers are looking for methods to decrease their input costs for peanuts due to the decreasing support prices. In many instances, using aglime in the pegging zone to supply calcium (Ca) for fruit development as well as to provide the proper soil pH for both peanuts and the rotational crops will help them meet their objective.

Deficiency Symptoms

It is rare that Ca is deficient to the point where peanut vine growth is stunted. However, the growth of peanuts without supplemental Ca visibly suffers compared to peanuts with adequate Ca supplied by preplant-incorporated dolomitic lime. The normal consequences of Ca deficiency are blackened plumules, high incidences of pod rot, and unfilled pods (termed "pops") resulting in low yield and substandard grade. Seed peanuts produced in Ca-deficient conditions will exhibit much poorer germination than those produced with an adequate Ca supply.

Soil Effects

Peanuts are most often grown on sandy soils which have limited ability to supply Ca to replenish that in the soil solution. Further, such soils are often relatively droughty. Since peanuts are relatively drought tolerant in comparison to most plants grown in semi-humid regions, they are often grown in locales with limited rainfall during some portion of pod and seed development. The problem of limited soil moisture in the developmental period adds to the Ca deficiency problems of peanuts since added Ca compounds will not dis-

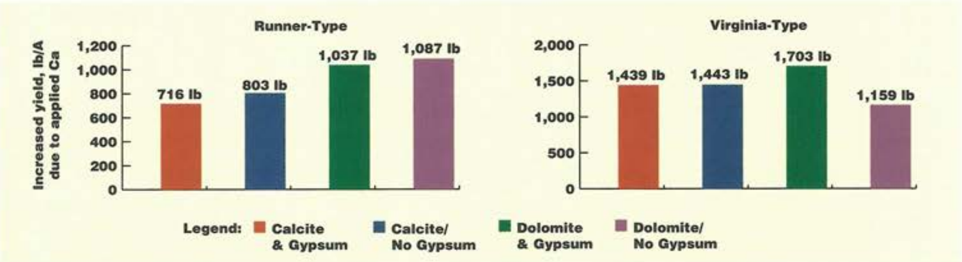

FIGURE 1. Increased yields of two types of peanuts due to calcite or dolomitic lime application preplant and gypsum at bloom.

GROWTH of peanuts without supplemental Ca (on left) suffers compared to peanuts with adequate Ca supplied by preplant-incorporated dolomitic lime (on right).

solve or move to the pod without soil moisture. Calcium in droughty soils is, therefore, not rapidly replenished in the soil solution close to the developing pod due low solubility of Ca sources and an inability to maintain a diffusion gradient toward the pod. The result is Ca deficiency.

Predicting Calcium Needs

Soil analysis is the most useful diagnostic tool for determining the need for supplemental Ca fertilization. Samples taken from the surface 6 to 8 inches prior to planting are often used. Soil test Ca in the pegging zone (top 3 inches), 10 to 14 days following planting, has been an important diagnostic tool for determining needs for supplemental Ca in the form of gypsum applied at bloom (BG) in Georgia. Data combined from the literature for 168 experiments conducted in Alabama and Georgia with small-seeded, runner-type peanuts showed that 95 percent of maximum yield was obtained when soil test Ca (Mehlich 1 extractable) was 200 parts per million (ppm). For the larger-seeded Virginia-type, soil test Ca is less valuable since supplemental Ca is normally recommended regardless of the soil test level. Recently, data from experiments conducted in Alabama, Georgia, North Carolina and Virginia were combined to show the effect of soil Ca on relative yield of Virginia-type peanuts. Maximum yield was attained at about 525 ppm Mehlich 1 Ca.

Calcium Sources

Getting soluble Ca into the pegging zone and maintaining a supply to replenish depletion by crop uptake and leaching can be especially difficult in sands. Very soluble Ca sources such as calcium chloride ($CaCl_2$) are generally expensive and short-lived due to leaching losses. Gypsum (calcium sulfate, $CaSO_4$) is much less soluble, but its application on the soil surface at first bloom is generally appropriate for supplying Ca over the 60-day period when there is a great requirement for available Ca.

In addition to mined gypsum, byproduct and phosphogypsum are also available in many places at lower cost. When soil Ca is less than the chosen threshold level, gypsum is either broadcast or banded over the peanut row at first bloom. Most prod-

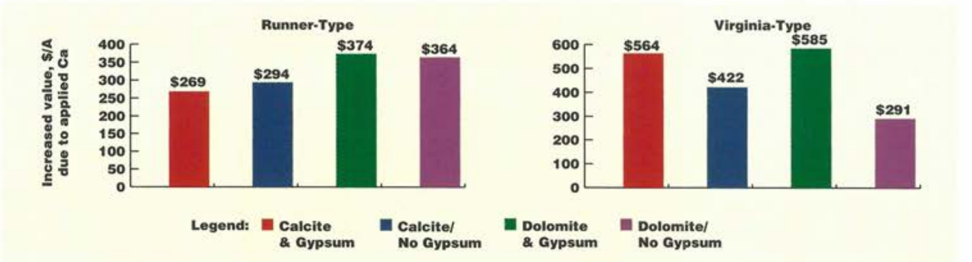

FIGURE 2. Increased gross value of two types of peanuts due to calcite or dolomitic lime application preplant and gypsum at bloom.

ucts have a range of particle sizes that solubilize over time to provide Ca. Gypsum has been a very successful source of Ca for peanuts; however, its application can add considerable cost to peanut production. Dependent on source and recommended rate of application, the applied costs may range from about $15 to $30/A.

Aglime is an important source of Ca for peanuts grown in the acidic soils of the southeastern U.S. and other regions. The main response of peanuts to aglime is due to the ability to supply Ca, whether it was applied for that purpose or to increase soil pH.

Field experiments conducted with runner-type peanuts in Alabama prior to 1980 indicated that aglime appeared to do little more than serve as a source of Ca and that spring-applied aglime provided all of the Ca needed for maximum yield and grade when it was properly incorporated into the pegging zone. Since good farmers will lime their soils for their chosen crop rotation, they should attempt to apply aglime in a manner that will supply Ca to their peanut crop and thereby reduce or eliminate the expense of a gypsum application. When aglime was applied to the soil prior to planting and incorporated to a shallow depth of 2 to 5 inches, adequate Ca was usually available for runner-type peanuts since yield responses to gypsum applied at bloom were rare following such applications.

Georgia Studies

Similar results were recently recorded in Georgia for runner-type peanuts, but preplant-incorporated aglime, applied at rates required to increase pH to the recommended value, did not supply adequate Ca for the larger-seeded Virginia-type peanut. A comparison of increased yields of pods resulting from preplant-incorporated calcite and dolomite (1,000 lb/A) with and without gypsum application at bloom (1,000 lb/A) is presented in **Figure 1**. The BG application did not increase yield of pods above the increase provided by the aglime alone for runner-type peanuts, indicating that the Ca requirements for top yield were satisfied by the aglime. Dolomite was superior to calcite for the runner-type peanuts on sandy soils in Georgia only because soil magnesium (Mg) was very low. However, dolomite at 1,000 lb/A did not supply enough Ca for Virginia-type peanuts as

POD DEVELOPMENT in peanuts with adequate Ca is shown at left, in contrast with Ca-deficient peanuts on the right.

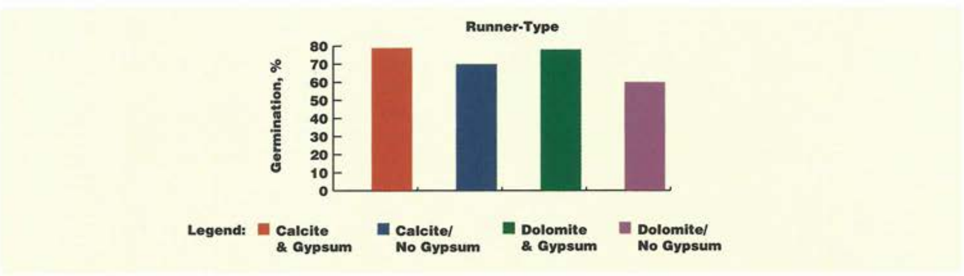

FIGURE 3. Effect of Ca source on germination of seed peanuts.

indicated by their additional response to BG after receiving the dolomite. Most rotational crops have a greater Mg requirement than peanuts, and their needs must also be considered in a liming program.

The gross value received for peanuts is also dependent on quality (grade), which includes several factors. Relations among Ca sources for runner-type peanuts are similar for yield and value (**Figure 2**), but value of the Virginia-type is increased greatly by BG following preplant-incorporated aglime.

Germination of seed produced from fields with inadequate Ca supplying power is poor. Preplant-incorporated aglime is effective in increasing the germination of seed produced (**Figure 3**), but gypsum applied at bloom increased germination percentage even when aglime had been applied preplant. For that reason, gypsum at bloom is always recommended for peanuts which will be used for seed.

Lime Placement

Lime placement is critical. Most aglime applications are incorporated much deeper than the peanut pegging zone either by harrows or plows. Nearly all peanut fields in the southern U.S. peanut belt are turned by moldboard plowing in order to bury trash and provide a loose bed for fruit development and removal. The modern moldboard plow essentially inverts the top foot of soil. If aglime is applied prior to plowing, it will remain far below the zone of nut development and not provide Ca needed by the peanut. We found no benefit to runner-type peanuts for preplow application (turned under). Benefits were equal for gypsum at bloom and preplant-incorporated aglime (**Figure 4**). Postplant incorporation to a depth of 3 inches was effective in increasing gross value, but not as effective as preplant incorporated.

Summary

Aglime preplant-incorporated for runner peanuts is effective for reducing pod rot, for increasing pod yield and increasing value per acre on sandy soils with pH less than 6 and a low Ca soil test.

Calcite and dolomite are both effective for runner-type peanuts. Dolomite should be the material of choice for fields with low or medium soil test Mg and calcite the choice for soil with high Mg.

When soil pH is less than 6 and aglime is recommended, preplant incorporation also appears to be a good means of applying Ca prior to planting Virginia-type peanuts. However, on sands, greatest yield, grade and value for the Virginia-type peanut will be attained by applying gypsum at bloom, regardless of the lime application. BC

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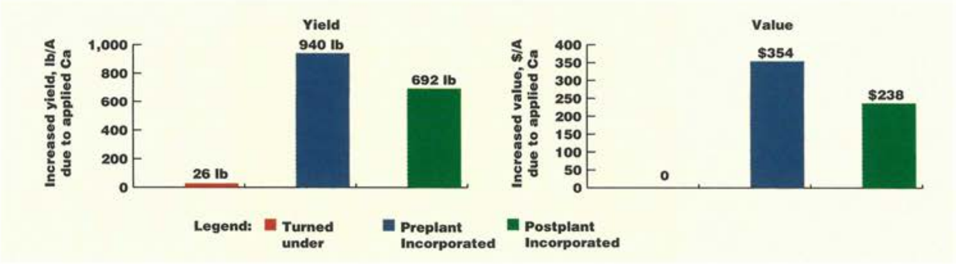


FIGURE 4. Yield and gross value of runner-type peanut as affected by aglime placement.

T E X A S

Liming Acid Soils for Ryegrass Production

By Vincent A. Haby, Jeff B. Hillard and Greg Clary

Annual ryegrass is an important cool-season forage crop that may be seeded into a prepared seedbed or overseeded into grass sods in the fall to extend grazing into late fall, winter, and spring in the southern and southwestern U.S. In the Coastal Plain area of Louisiana and Texas more than one million acres are planted to ryegrass each year.

Liming an acid soil for ryegrass production increased forage yields over a four-year period. The value of increased forage yield for the 1986 season was estimated to exceed $400 per acre.

Studies at the Texas A&M University Agricultural Research and Extension Center at Overton found that ryegrass is relatively intolerant to soil acidity. Strongly acid Coastal Plain soils, pH 4.0 to 5.0, normally have low levels of extractable calcium (Ca) and magnesium (Mg) and high levels of extractable aluminum (Al).

Annual ryegrass is relatively intolerant to soil acidity. Marshall ryegrass response to incorporation of 1.7 tons/A of 62 percent effective calcium carbonate equivalent (ECCE) aglime into an acid (pH 4.7) Lilbert loamy fine sand two years earlier is shown in the photo. Application of aglime at a rate of 0.3 ton/A on July 1 raised soil pH from 4.7 to 4.8 by fall (**Table 1**). It decreased extractable soil Al from 23.4 to 19.6 parts per million (ppm), and had no effect on soil extractable manganese (Mn). Ryegrass forage production the following year was 4,523 lb/A due to this treatment. An application of 1.7 tons/A of aglime increased ryegrass forage yields to 5,379 lb/A. The unlimed soil produced only 2,783 lb of forage per acre.

After three years of nitrogen (N) treatments totaling 1,214 lb/A for ryegrass and Coastal bermudagrass, pH in the soil treated with 1.7 tons of aglime/A had declined to 4.6, but ryegrass yield was still 5,415 lb/A. Extractable Al in soil treated with 0.3 ton of aglime/A was 23.4 compared to 13.1 ppm at the 1.7 ton/A aglime rate. Extractable Ca was 296 ppm in soil treated with the high rate compared to 162 and 169 ppm for the control and 0.3 ton/A rate of aglime, respectively. The decreased extractable Al and increased level of extractable Ca appeared to relate better to ryegrass yield than did soil pH.

Figure 1 shows the greater neutralizing effect of aglime with ECCE 100 as compared to ECCE 62 aglime on a Darco

TABLE 1. Soil pH and Marshall ryegrass response to aglime incorporated into a Lilbert loamy fine sand.

Aglime rate, tons/A	Fall of application year, pH	Dry matter 1984, lb/A	pH, 1985	Dry matter 1986, lb/A	pH, 1987	Dry matter 1987, lb/A
0	4.7	2,783	4.5	3,434	4.5	633
0.3	4.8	4,523	4.7	4,576	4.5	981
1.7	5.7	5,379	6.2	7,422	4.6	5,415

Texas

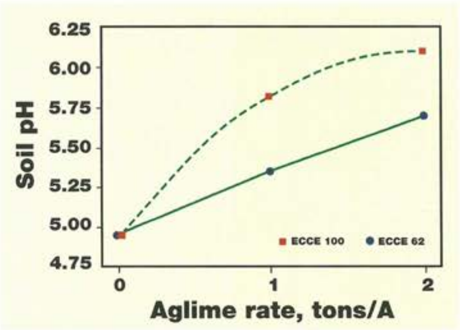


FIGURE 1. Impact of aglime rate and effective $CaCO_3$ equivalent (ECCE) on pH in the 0 to 6 inch soil depth two and a half years after treatment.

APPLICATION of 1.7 tons of aglime per acre to a Lilbert soil with pH 4.7 increased forage yields an average of 3,785 lb/A over three production seasons in a Texas Agricultural Experiment Station study.

loamy sand. One ton of ECCE 100 aglime raised pH higher than did 2 tons/A of ECCE 62.

Economic estimates of the value of the ryegrass response to aglime applications projected that had the increased forage been grazed by stocker cattle weighing 450 lb each, the added monetary return over the cost of the lime in 1986, three years after application, could still exceed $400/A. The response curve predicted that the marginal rate of return may have occurred beyond 2 tons of aglime per acre (**Table 2**).

Summary

Recent Texas research on treatment of acid, Coastal Plain soils with aglime for ryegrass production emphasizes the improvement in forage yield that can be obtained. Producers need to think of aglime as an investment that provides excellent returns over multiple years from increased ryegrass production. BC

Dr. Haby and Dr. Clary are located at the Texas A&M University Agricultural Research and Extension Center, Overton, TX. Dr. Hillard is with Louisiana Tech University.

TABLE 2. Economic evaluation of estimated livestock gains from increased yield of annual ryegrass in 1986 due to liming.

Aglime application, tons/A	Ryegrass yield, dry matter lb/A	Yield increase, dry matter lb/A	Added incremental cost[1], $/A	Added return[2], $/A
0	3,233	—	—	—
0.5	5,148	1,915	12	186.00
1.0	6,503	1,355	12	132.00
1.5	7,298	795	12	77.00
2.0	7,533	235	12	23.00

Marshall variety.

[1]Aglime cost estimated at $24/ton applied.

[2]Forage consumption and rates of gain estimated using a computerized simulation program. Based on $85.00/cwt steers.

PENNSYLVANIA

Lime Needs under No-till Conditions

By Douglas B. Beegle

Conservation tillage is becoming more and more common in North America. It is usually accompanied by an increase in surface acidity from the long-term surface application of ammonium-containing fertilizers and manures. This lower surface pH can result in aluminum (Al) toxicity which can limit root growth and lead to reduced effectiveness of triazine herbicides.

Pennsylvania studies show that surface applications of aglime in no-till systems primarily affect the surface 2 inches of soil. Still, this change in soil pH can benefit crops and affect herbicide performance.

The effects of liming are limited in the short term to soil in close proximity to the limestone particles. For maximum effectiveness, recommendations call for limestone to be mixed thoroughly with the soil. But, in reduced tillage systems, mixing is very limited. That raises the question for conservation tillage systems, particularly no-till crop production, "Can aglime be applied to the soil surface and effectively change the soil pH?"

Penn State Studies

A study was initiated at Penn State to look at the effects of surface application of lime on a very acid, long-term no-till soil. For the preceding eight years, the field had been in no-till corn production with no aglime applied. The initial pH of the plow layer was 5.1 and the pH of the surface 2 inches was 4.5. The lime recommendation, based on the SMP buffer pH and a target pH of 6.5, was 6,000 lb/A calcium carbonate equivalent (CCE). The study included four aglime rates (0, 3,000, 6,000, 9,000 lb CCE/A) and liming programs ranging from applying aglime every year to once every five years. Each year the soil was sampled in the spring in 2-inch increments to a depth of 6 inches. No-till corn was grown for the first seven years, no-till soybeans for next two years, oats for one year and wheat for one year.

Results

Soil samples were collected in the spring of each year for the first nine years of the study. The recommended liming program, 6,000 lb CCE/A every third year (**Figure 1**), changed the soil pH in the surface 2 inches within the first year after application. Most of the change occurred within the first two months after spring liming. That sort of change was expected because the aglime used was high quality with 90 percent passing a 100 mesh sieve. Spot checks indicated that most of the pH change actually occurred in the surface half inch of soil. There was little change in the soil pH below the surface 2 inches until about the fourth year of the study following subsequent lime applications.

A second program, 6,000 lb CCE/A initially and 3,000 lb CCE/A per year after two years, was of substantial interest because of speculation that more frequent, smaller applications of lime may be necessary in no-till systems. Soil pH values (**Figure 2**) indicated little difference between the standard program...liming every third year...and the annual lime applications.

Aglime applications resulted in slight increases in corn yield. Yield increases may have been limited by compaction from the liming operation, especially in the more frequent liming programs. Wheat showed the greatest yield response in the tenth year of the study (**Table 1**).

Corn ear leaf samples were analyzed in several years of the study. There were significant effects on plant tissue nutrient concentrations immediately after liming even though the pH effect was limited to the soil surface. Data indicated a significant increase in calcium (Ca) concentrations and a decrease in manganese (Mn) (**Table 2**). The Ca levels in all of the plots were in the sufficient range. The Mn levels in the check and 3,000 lb CCE/A treatments were in the high range and the other two treatments were in the sufficient range for corn. Still, the rapid effect on nutrient availability, when the pH change was limited to the soil surface, was a little surprising. However, this could be explained by increased root growth near the surface in a high residue system.

TABLE 1. Wheat yield response due to liming.

Aglime rate, lb/A	Wheat yield, bu/A
0	52
3,000	69
6,000	71
9,000	69

TABLE 2. Effects of liming on corn ear leaf Ca and Mn in the first year after application.

Aglime rate, lb/A	Calcium, %	Manganese, ppm
0	0.51	198
3,000	0.58	159
6,000	0.57	133
9,000	0.58	122

A triazine weed control evaluation was included in the early years of this study. This work showed that the initial liming which only affected the pH at the soil surface did improve the efficacy of the triazine herbicides. This was expected since many of the herbicides work in this shallow layer near the soil surface.

Summary

This study indicated that surface application of aglime will rapidly change the pH of surface soil. It also indicated

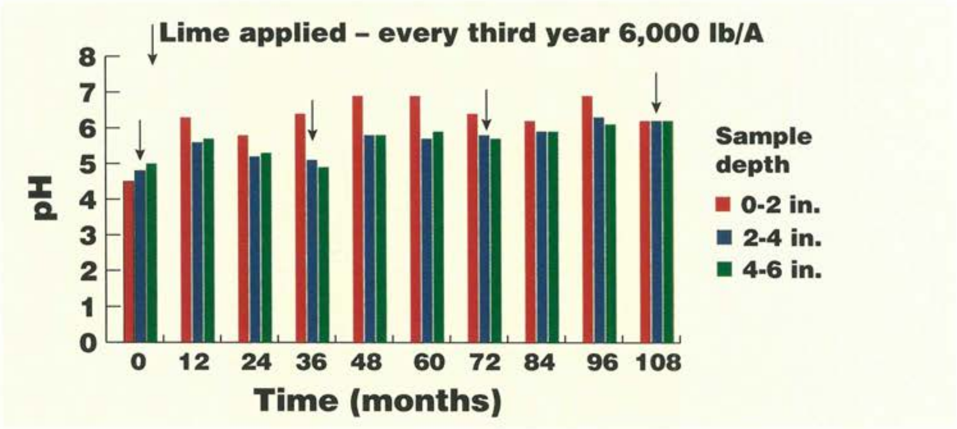


FIGURE 1. Soil pH versus time for a no-till soil limed at 6,000 lb/A every third year.

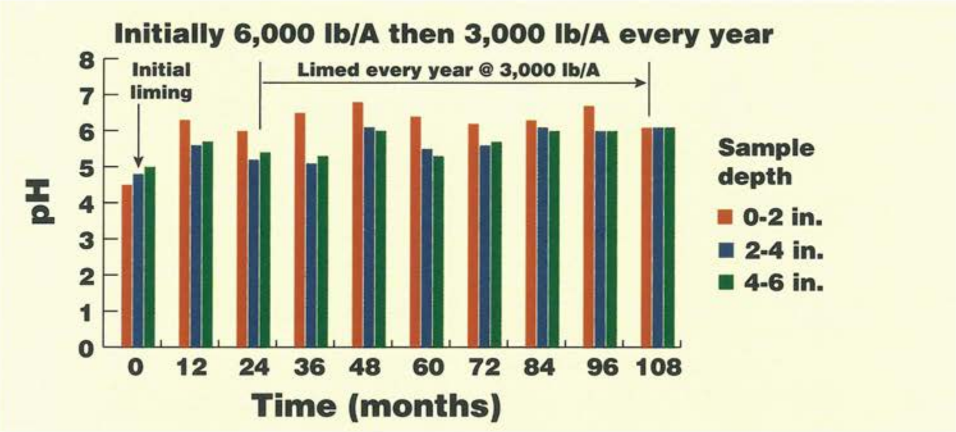


FIGURE 2. Soil pH versus time for a no-till soil limed at 6,000 lb/A initially and then at 3,000 lb/A annually after the second year.

that even this shallow pH improvement could affect herbicide activity and nutrient availability. The study showed that a very long time is required for aglime to have much effect on the soil pH below the surface 2 inches in a no-till system. Finally, there seems to be little justification for more frequent liming in no-till systems.

The current recommendation for liming no-till systems is effective. On an acid soil, aglime should be incorporated to adjust the soil pH to the desired level in the entire plow layer before no-till crop production is initiated. If the soil pH is in the desired range initially, it can be maintained by surface applications of limestone in no-till systems. If a regular liming program is followed and soil pH is not allowed to drop to very low levels, further incorporation of aglime applications should not be necessary. Where incorporation is not possible, there are beneficial effects of surface application of aglime to acid no-till soils even though the immediate effect will only be near the soil surface. Surface liming approximately every three years based on a regular soil testing program should be adequate for no-till systems. BC

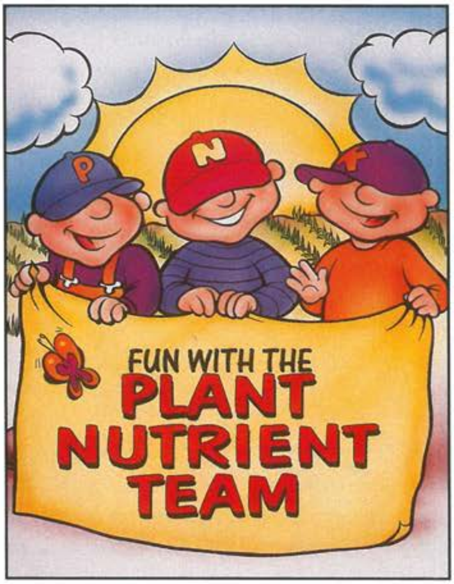
Dr. Beegle is Professor of Agronomy, Department of Agronomy, Pennsylvania State University, University Park, PA 16802.

International Soil Fertility Manual Now Available

Since 1978, PPI has distributed over 75,000 copies of the Soil Fertility Manual. In recent years, there has been growing interest in a version of the manual adapted to international audiences and presented in metric units. Now, PPI is pleased to announce that the 114-page International Soil Fertility Manual is available.

To order a single copy, send $30.00 in U.S. funds ($15.00 for PPI member companies) payable to "Potash & Phosphate Institute." U.S. and Canada orders add $4.00 shipping, all other countries add $7.00. If ordering multiple copies contact: Potash & Phosphate Institute, 655 Engineering Dr., Ste. 110, Norcross, GA 30092-2843; phone (770) 447-0335, ext. 213 or 214; fax (770) 448-0439. BC

FUN WITH THE PLANT NUTRIENT TEAM



An educational activity book for use in kindergarten through third grade is now available. The book, a project of PPI and FAR, encompasses information about the importance of plant nutrients and basic concepts of food and fiber production.

"Because so many children today don't grow up on farms, they may not realize how plants grow and where food and fiber products originate," said Dr. David W. Dibb, President of PPI. "Our challenge was to produce an activity book that will be entertaining but also educational for young children. We believe we have met the challenge with *Fun with the Plant Nutrient Team.*"

The 24-page book features nitrogen (N), phosphorus (P) and potasssium (K) as characters in a variety of activities such as dot-to-dot, word puzzles, coloring, mazes, matching pictures and experiments. Principles such as soil conservation and science as part of modern agriculture are included.

A sample copy of *Fun with the Plant Nutrient Team* can be purchased for $3.00. Additional copies are $1.00 each, plus shipping/handling. A teacher's guide with additional information, experiments, facts and resources is also available on request.

Send orders to: Potash & Phosphate Institute, 655 Engineering Drive, Suite 110, Norcross, GA 30092-2843. Phone 770-447-0335, ext. 213 or 214; fax 770-448-0439.

CALIFORNIA

Foliar Boron Application Enhances Almond Yields

By Patrick Brown, Hening Hu, Agnes Nyomora and Mark Freeman

> A three-year study in California shows that foliar boron (B) applications can increase yield in almonds even where there are no visible leaf symptoms of B deficiency. Data suggest that foliar applications act specifically to enhance the number of flowers that set fruit.

Boron deficiency occurs widely in the fruit-growing regions of California and is more common in the lighter textured soils supplied with high quality irrigation water. Severe B deficiency, however, resulting in characteristic leaf symptoms, is relatively uncommon and can be effectively controlled with soil application of B fertilizers.

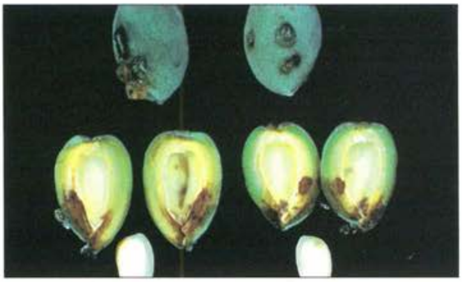
There is mounting evidence in the fruit growing regions of California, Oregon and Washington (pistachio, almond, apple, pear) that alleviation of foliar symptoms of B deficiency may not be sufficient to bring the plant to full yield. Indeed, there are many examples in which yield has been increased by foliar B application to plants with no visual signs of B deficiency. This observation and the well documented role of B in pollen growth and fertilization suggest that flowering and fruit set may have a higher demand for B than does leaf growth. This phenomenon was investigated over a three-year period in a commercial almond orchard in Fresno County, CA.

Extensive experimentation with many different crop species demonstrates that both soil and foliar applications of B can effectively increase tissue B levels above the critical value of 30 to 60 parts per million (ppm) for vegetative growth of almond. Sodium borate (Solubor) and boric acid formulations are both rapidly absorbed by almond when leaves are present and will effectively increase leaf B concentrations. However, since B is required for effective nut set it is also necessary to ensure that flower buds have adequate B supplies to carry them through flowering, fertilization and nut set. Given the highly variable nature of soil B uptake that results from changes in water availability, temperature and organic matter content, it is suggested that a supplemental foliar B application may be beneficial. In comparison with the high value of crops such as almond, the cost of foliar B is low. Since the number of nuts set is critical to productivity, foliar application of B is worthwhile whenever B levels are moderate or low.

California Almond Studies

Trials were conducted in a low B region of Fresno County. Though almond trees in this area did not show distinctive B deficiency symptoms in vegetative parts, B concentration measured in July leaf samples were <30 ppm and nut production was very low. The following symptoms were observed: trees flowered early and were very prolific, but within two weeks of flowering large numbers of flowers and small nuts had fallen from the tree; after an additional two weeks, essentially all nuts had been aborted with less

ALMONDS on the bottom row demonstrate a boron deficiency.



EXCESSIVE production of gum produces unsuitable almonds.

than 5 percent of the initial flowers resulting in a viable nut. In many cases these trees then became excessively vigorous as a result of the lack of carbon demand from the developing fruit. At maturity, nuts on some varieties had excessive production of gum and were unsuitable for consumption. Yield was less than 20 percent of the county average for trees of this age in similar climatic conditions. Reports of similar symptoms in pear and pistachio suggested this may be the result of a marginal deficiency of B. Based on the success of our work in pistachio, a series of experiments was established to develop an effective B foliar spray program for almond.

Foliar Boron Application

Foliar B sprays were applied at 0, 1, 2, and 5 lb/A sodium borate (20.5 percent B) in 100 gallons of water to a 15-year old almond orchard. Applications were made at three different times over a one-year period. Treatments were applied to 15 replicate trees. Number of flowers, percent flowers setting fruit, leaf, bud and flower B concentrations, as well as total yield were determined. The experiment was repeated for three consecutive years. The results of the 1994 season presented here are representative of the entire experiment.

Applications of foliar B two weeks after nut harvest (September 1993) resulted in a significant increase in bud B concentration sampled the following spring (**Figure 1**). Boron concentrations increased from 20 to 90 ppm as B increased from 0 to 5 lb sodium borate/100 gallons. Leaf B concentrations sampled during the summer (**Figure 2**) also increased in direct proportion to B application.

Increased concentrations of B in flower buds (**Figure 1**), flowers and pollen (data not shown) resulted in a significant increase in the viability of almond pollen from 55 percent to >75 percent (**Figure 3**).

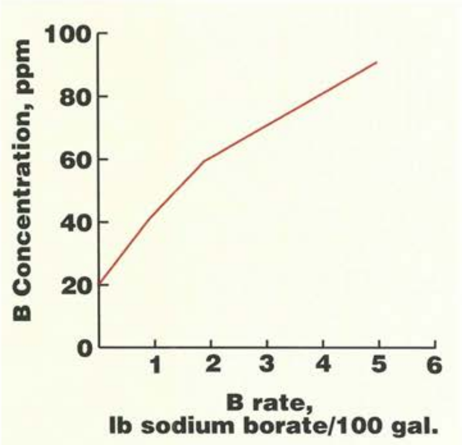


FIGURE 1. Effect of foliar B application on concentration in bud (February sample). Foliar B applied the previous September.

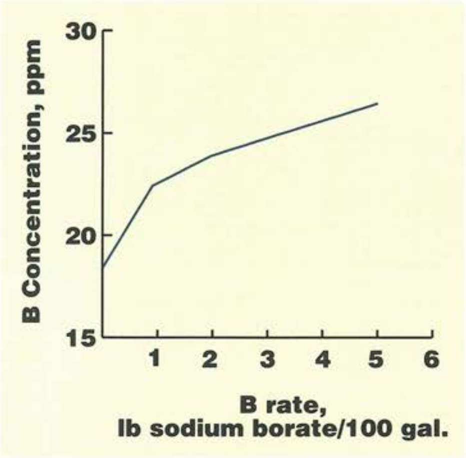


FIGURE 2. Effect of foliar B application on concentration in leaves (July sample). Foliar B applied the previous September.

Foliar B sprays also dramatically improved nut set, which is the primary determinant of yield (**Figure 4**) and profitability. Nut set increased from 45 percent to 75 percent with the application of 1 or 2 lb sodium borate/100 gal., but decreased to 55 percent when higher B rates were used. It is likely that the increase in nut set in response to B application was the result of the observed increase in pollen viability.

To determine the optimum time for B applications, trials were performed applying 1 and 2 lb sodium borate/100 gal. in September 1993, December 1993, or February 1994, to almond. Yields were collected in August 1994. Boron application in September 1993 (**Figure 5**) enhanced fruit yield by 67 percent. No other application date significantly affected yield in this or any other year. The need for B in flower buds may require that it be applied during bud formation, which occurs in late summer in almond. Foliar B application appears to be the most effective way to supply B at this critical stage of development.

Summary

The results of this and similar research with pistachio suggest that foliar B application can increase yield in nut crops even in the absence of any visible (i.e. vegetative) signs of B deficiency. The

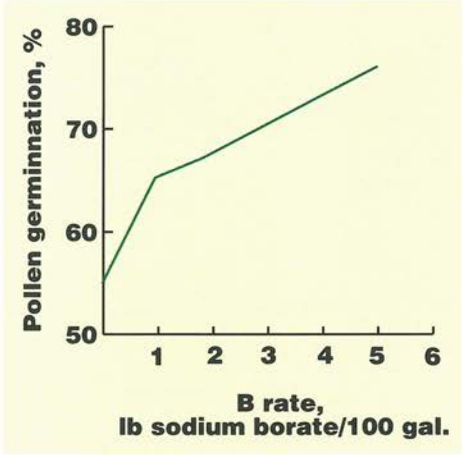


FIGURE 3. Effect of foliar B on pollen germination rate in almond. Foliar B applied the previous September.

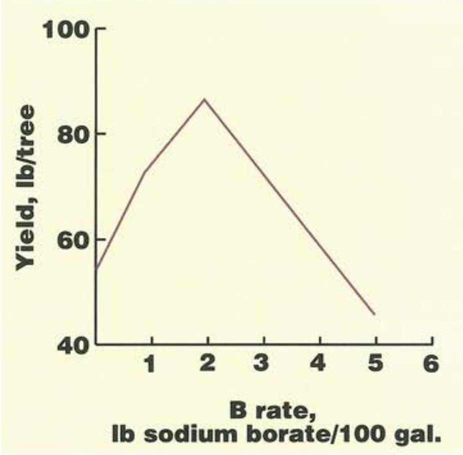


FIGURE 4. Effect of foliar B on almond yield. Foliar B applied the previous September.

application rates utilized in these foliar trials are low in comparison to normal soil application rates and when provided in even slight excess can reduce yields. In both pistachio and almond there is a specific brief period at which foliar B sprays are effective. These observations suggest that foliar B applications act specifically to enhance the number of flowers that set fruit. Soil applications that enhance whole tree B levels may not have this same specific effect.

Soil applications of B effectively correct chronic B deficiency and should be used in programs where soil and water B levels are low. A combination of soil application plus foliar B application is recommended when leaf B levels are below 30 ppm, while foliar B applications should be beneficial in areas of moderate B status (30 to 50 ppm).

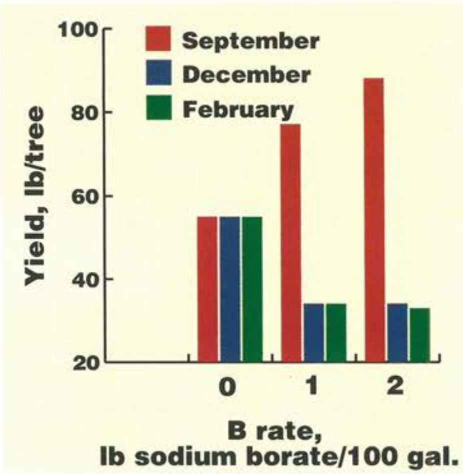


FIGURE 5. Effect of foliar B application on yield at three times of application.

Boron toxicity is a possibility in much of California and should be monitored closely. Leaf tissue B in excess of 50 ppm B may indicate potential B toxicity and can be confirmed by sampling almond hulls in July. A hull value in excess of 200 ppm suggests B toxicity. Under these conditions no application of B is warranted. BC

Dr. Brown is Associate Professor, Dr. Hening Hu and Dr. Nyomora are Postdoctoral Researchers, Department of Pomology, University of California-Davis, and Mr. Freeman is Farm Advisor, University of California Cooperative Extension, Fresno, CA.

Research Notes

Florida: Bahiagrass Response to Dolomitic Limestone

Bahiagrass is an important forage crop in the southeastern U.S. A four-year field study on a Pomona fine sand in Florida demonstrated the importance of dolomitic lime for bahiagrass production on low pH soils.

Four rates of dolomitic lime (0,1,2, and 3 tons/A) were compared in 1989 through 1992. Dolomitic lime increased soil pH and reduced exchangeable aluminum (Al). It also increased yields, which ranged from 3.1 to 3.3 tons/A in 1989, 3.4 to 3.9 tons/A in 1990, 3.7 to 4.9 tons/A in 1991 and 3.4 to 4.3 tons/A in 1992. Data indicate that part of the yield response is due to addition of magnesium (Mg) from the dolomite. Year to year variation in yields was also affected by rainfall differences. BC

Source: J.E. Rechcigl, P. Mislevy and H. Ibrikci. Journal of Production Agriculture, 8:249-253 (1995).

Research Tracks Nitrogen Dissipation Patterns in Rice Production

By Garry N. McCauley

Nitrogen is the primary fertilizer nutrient in rice and other crop production. Because it is highly mobile in most soils, it is easily leached and has the potential to reach and pollute groundwater if not properly managed. Further, excess nitrate-N (NO_3-N) in surface water can contribute to algal blooms and result in reduced oxygen for aquatic life. Nitrate-N is the N form that is of greatest concern because of its relationship to human health, particularly infants, unborn babies and the elderly. The U.S. Environmental Protection Agency (EPA) has set a safe drinking water standard of 10 parts per million (ppm) NO_3-N.

Nitrogen (N) is the nutrient most often associated with water quality. Since most Texas rice production is concentrated in areas near the Gulf Coast, N in flood waters leaving rice fields can impact surrounding areas, including coastal waters. This study was established to evaluate the environmental impact of N, phosphorus (P) and potassium (K) fertilization of rice grown under flood management. Earlier articles (*Better Crops*, Vol. 79, No. 3, 1995 and Vol. 79, No. 4, 1995) dealt with P and K. This one discusses N.

Historical data and recent studies have shown that movement of chemicals in groundwater is not a problem in Texas rice soils. These soils have clayey layers with high cation exchange capacities and hold charged chemicals, slowly releasing them back to the soil solution as needed. Nitrate-N moves downward very slowly in these soils. Its leaching into the groundwater is not considered a problem.

This study was designed to measure the environmental impact of N, P and K fertilization of rice under flood management.

Twenty producers in a four-county area (Colorado, Jackson, Matagorda and Wharton) were recruited by county Extension agents to participate in the study. Producers took a water sample at the inlet and outlet of each test field following each rain and flush irrigation. After flood establishment, inlet and outlet samples were taken when the flood reached the bottom of the field and at three day intervals until four samples were taken or at least 12 days after flood establishment.

The 20 producers took a total of 220 samples at 116 different times. There were 104 matched inlet and outlet samples, with 12 outlet samples being taken when no inlet water was available.

Figure 1 shows the concentration distribution of the 220 samples. Most of the samples ... 94 percent ... contained 2.0 ppm NO_3-N or less. Only two exceeded the drinking water limit of 10 ppm. These results support earlier research (1992-93) which showed that NO_3-N concentrations in flood water are low most of the time.

To allow for detailed interpretation, samples were broken into seven groups (**Table 1**).

Studying the seven groups reveals that A through E can only be interpreted

TABLE 1. Seven water sample groups used to determine potential effects of N fertilization.

A = No inlet—outlet non-detectable
B = Concentration declined to non-detectable
C = Concentration declined, still detectable
D = Inlet and outlet samples non-detectable
E = Detectable levels—no change
F = Concentration increased
G = No inlet sample—detectable level in outlet

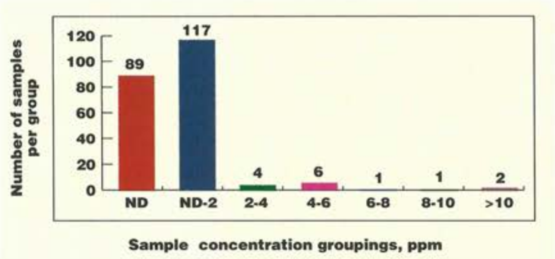


FIGURE 1. Concentration distribution of 220 NO_3-N rice field water quality samples. (ND=Non-detectable, <0.1 ppm)

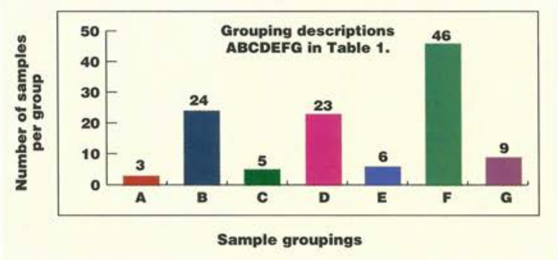


FIGURE 2. Distribution of inlet-outlet sample change in NO_3-N concentration for 116 rice field water samples.

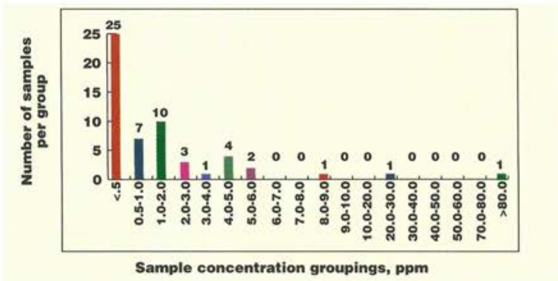


FIGURE 3. Distribution of NO_3-N concentration increases from inlet to outlet for 55 rice field water samples that increased. (ND=Non-detectable, <0.1 ppm)

to have a neutral or positive environmental impact. Group F would be a negative environmental factor, the magnitude depending on the amount of concentration increase. The impact of G group can not be determined because there was only one sample taken, but it is assumed to be negative (conservative interpretation).

Only three of the 55 samples in groups F and G should be of environmental concern (**Figure 2**). They were the ones of the 104 matched sample pairs that showed NO_3-N concentrations high enough to create a potential environmental problem, as shown in **Figure 3**. Nine of the 55 samples could not be evaluated, however, because there was not a matching inlet sample.

The above results support earlier research which showed that in only a small percentage of the cases would NO_3-N in a rice field cause problems if discharged into waterways. The key to water purification in a vegetative lagoon (such as a flooded rice field) is retention or flow time.

In summary, there are few instances where NO_3-N concentrations in rice field runoff may be high enough to be an environmental concern. In those individual cases where concentrations do pose a potential threat to water quality, they should be evaluated to determine how N management can be modified to eliminate the problem. BC

Dr. McCauley is Associate Professor, Texas A&M University System, Eagle Lake, TX.

Information Agriculture Conference

PLANNED FOR JULY 30 - AUGUST 1, 1996

Dates for the 1996 Information Agriculture Conference are now set for Tuesday, July 30 through Thursday, August 1. The event will take place at the Krannert Center for the Performing Arts, University of Illinois, Urbana. Plans were announced by Dr. David W. Dibb, President of PPI.

Dr. Harold F. Reetz, Jr., PPI Midwest Director, Monticello, IL, will serve as chairman of the coordinating committee for the conference. Sponsors will include PPI, the Foundation for Agronomic Research (FAR), National Center for Supercomputer Applications (NCSA), University of Illinois College of Agricultural, Consumer and Environmental Sciences and others to be announced.

The conference will focus on site-specific crop and soil management technology and computer communication systems for agriculture. Program features will include yield mapping and interpretation, variable rate systems, data management, remote sensing, global positioning system potential, geographic information systems, and communication developments.

An exhibit hall will allow space for companies and organizations to display products and services related to modern crop production and information. An area will also be available for volunteer "poster" presentations where researchers and others can share results of studies and field experience.

Registration fees are $200 per individual before July 15, 1996 (students $100). Exhibitor fee is $300 for a standard booth area. The fee includes conference registration for one person.

THE CYBERFARM demonstration area will feature more on electronic information and record systems at the 1996 Information Agriculture Conference.

For registration and lodging information, contact:

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Potential co-sponsors and those interested in supporting the conference may contact Dr. Larry S. Murphy at the PPI Manhattan, KS, office: (913) 776-0273

Additional details will be available on the Information Agriculture Conference Home Page on the Internet at:
http://w3.ag.uiuc.edu/INFOAG/
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http://www.agriculture.com/contents/ppi/ppiindex.html.

Conversion Factors for Metric and U.S. Units

To convert column 1 into column 2, multiply by:	Column 1	Column 2	To convert column 2 into column 1, multiply by:
LENGTH			
0.621	kilometer, km	mile, mi	1.609
1.094	meter, m	yard, yd	0.914
0.394	centimeter, cm	inch, in	2.54
AREA			
0.386	kilometer^2, km^2	mile^2, mi^2	2.590
247.1	kilometer^2, km^2	acre, acre	0.00405
2.471	hectare, ha	acre, acre	0.405
VOLUME			
0.00973	cubic meter, m^3	acre-inch	102.8
3.532	hectoliter, hl	cubic foot, ft^3	0.2832
2.838	hectoliter, hl	bushel, bu	0.352
0.0284	liter, 1	bushel, bu	35.24
1.057	liter, 1	quart (liquid), qt.	0.946
MASS			
1.102	tonne (metric)	ton (short)	0.9072
2.205	quintal, q	hundredweight, cwt (short)	0.454
2.205	kilogram, kg	pound, lb	0.454
0.035	gram, g	ounce (avdp), oz	28.35
YIELD OR RATE			
0.446	tonne(metric)/hectare	ton (short)/acre	2.240
0.891	kg/ha	lb/acre	1.12
0.891	quintal/hectare	hundredweight/acre	1.12
1.15	hectoliter/hectare,hl/ha	bu/acre	0.87
TEMPERATURE			
(1.8 x C) + 32	Celcius, C	Fahrenheit, F	0.56 x (F-32)
	-17.8°	0°F	
	0°C	32°F	
	20°C	68°F	
	100°C	212°F	

METRIC PREFIX DEFINITIONS

mega	1,000,000	deca	10	centi	0.01
kilo	1,000	basic metric unit	1	milli	0.001
hecto	100	deci	0.1	micro	0.000001

TO CONVERT U.S. CROP YIELDS FROM BUSHELS PER ACRE (bu/A) TO METRICS

Corn–bu/A x 0.063 = tonnes/ha
Soybeans–bu/A x 0.067 = tonnes/ha
Wheat–bu/A x 0.067 = tonnes/ha
Grain Sorghum–bu/A x 0.056 = tonnes/ha

SOUTH AMERICA

Liming Tropical Soils – A Management Challenge

By José Espinosa

Soils that are dominated by 2:1 clays (montmorillonite, vermiculite, illite) are usually found in temperate zones of the globe. However, they also occur in tropical and subtropical areas. These soils behave differently than the typical tropical red soils (Ultisols and Oxisols) which are dominated by kaolinite and by iron (Fe) and aluminum (Al) oxides and hydroxides. And they are not the same as soils developed from volcanic ash (Andisols) that are widely spread over the world. These important differences determine the approach used to evaluate lime requirements.

Research in several South American countries has emphasized the importance of lowering exchangeable aluminum (Al) through liming. Objectives of lime applications for temperate and tropical or ash derived soils are quite different.

In soils dominated by 2:1 clays, the reduction in base saturation from loss of potassium (K), calcium (Ca), and magnesium (Mg) leads to increasing acidity. This increased acidity in turn leads to the subsequent breakdown of the clay material and to the release of structural Al, which occupies the exchange sites left by the lost bases. This is the reason why these soils can be easily limed to a pH of near 7.0, which is optimal for the production of many crops. During the liming process there is little change in cation exchange capacity (CEC)...soils of permanent charge.

Determining Lime Needs — Temperate Soils

Common methods for determining lime needs in soils dominated by permanent charge clays are based on buffered solutions. The most popular of these methods is the SMP method developed to determine lime needs in acid soils of the temperate zones of the U.S. The equilibrium pH value of a suspension made of soil – water - buffer solution is correlated with the amount of lime needed to increase soil pH to a certain value, using a $CaCO_3$ incubation procedure, in the same soil sample. In this way, recommendations can be developed to indicate the amount of time required to bring soil pH to a particular value. **Table 1** presents an example of liming recommendations based on calibration of a SMP buffer solution.

Liming Tropical and Ash Soils

However, the approach for liming tropical red soils and soils derived from volcanic ash is quite different. In Ultisols and Oxisols, Al and Fe are present in mineral clays that are stable at pH values as low as 5.0. In this case, Al is buried in the clay particle. It is not a threat to plant growth until soil pH reaches a value where the oxides and kaolinite dissolve, bringing Al...sometimes in toxic quantities...into the soil solution. When this situation arises it is advisable to raise soil pH to about 5.5. This will allow Al precipitation and appreciable increase in CEC (soils of variable charge), **Table 2.** In this pH range, crop growth and yield

TABLE 1. Liming rates determined using SMP buffer solutions.

SMP Index[1]	5.5	6.0	6.5
	Desired pH after liming		
	Lime rate, t/ha		
4.4	15.0	21.0	29.0
4.6	10.9	15.1	20.0
4.8	8.5	11.9	15.7
5.0	6.9	9.7	12.9
5.2	5.5	8.0	10.6
5.4	4.4	6.5	8.7
5.6	3.3	5.1	7.0
5.8	2.3	3.9	5.5
6.0	1.4	2.8	4.1
6.2	0.6	1.7	2.7
6.4	0.0	0.0	1.5

[1]pH of the suspension soil–water–buffer solution.

are excellent, **Table 3.**

In tropical soils, the determination of lime requirements using buffered solutions does not work adequately. Using this approach, large amounts of lime are recommended to force soil pH to values in the 6.0 to 7.0 range. However, only a moderate amount of lime is needed to raise soil pH to values high enough to precipitate Al in the top layer in this type of soil (around pH 5.5). A better approach to develop liming recommendations is to take into account the amount of exchangeable Al present in the topsoil. Following this concept, lime requirements for most tropical soils can be predicted applying the following equation:

$$CaCO_3 \text{ (t/ha)} = \text{Factor x cmol Al/kg soil}$$

The factor used can vary from 1.5 to 3.0 depending on the crop characteristics and the soil type and can be fine tuned by the agronomist or farmer working at any specific site.

The primary goal of this approach is to neutralize all Al, but there are Al-tolerant crops that can grow and yield satisfactorily at moderate to high Al saturation of the exchange complex. Since not all Al needs to be precipitated, a lower amount of lime can be used...to reduce Al saturation to the desired level. In most of these cases, the lime applied is used to overcome Ca and Mg deficiencies which can be limiting to plant growth in weathered soils of low CEC. Coffee, banana, oil palm, pineapple, and a number of tropical grasses and legumes are among the crops that tolerate high Al saturation.

Plant breeding has developed cultivars of certain crops that are also tolerant of high soil Al saturation. Examples are Orizyca sabana 6 (upland rice) and Sorghica real 60 (sorghum) developed for Oxisols from the eastern savannas of Colombia. Lime recommendations for Orizyca sabana 6 upland rice range from 250 to 500 kg/ha of dolomite, with the only purpose of providing Ca and Mg to the crop.

TABLE 2. Effect of lime application to a red Ultisol from Panama.

Treatment	pH	Ca	Mg	K	Al	Effective CEC
				cmol/kg		
No lime	4.9	1.79	1.11	0.11	2.15	5.18
Lime (4 t/ha)	5.8	7.90	6.73	0.14	0.09	14.85

Another common method used to calculate lime requirements, related to Al saturation, is based on soil base saturation. Though it has been determined that base saturation does not influence yield in soils dominated by 2:1 clays, this parameter is very important in highly weathered soil (Ultisols and Oxisols) of low CEC and low Ca and Mg content. As indicated above, lime is used not only as an amendment in these types of soils, but also as a source of Ca and Mg. Research has demonstrated that, within certain limits, higher base saturation in weathered soils improves fertility and increases crop yields.

A method for determining lime requirement was developed taking into account a targeted soil base saturation which is attained by lime application. Brazilian experience indicates, for example, that the best coffee yields are obtained at 60 percent saturation. In other words, coffee can grow satisfactorily in a soil with up to 40 percent Al saturation. According to these criteria, lime requirements can be calculated using the following equation:

$$CaCO_3\ (t/ha) = \frac{(BS_2 - BS_1) \times CEC}{100}$$

BS_1 = Initial base saturation
BS_2 = Required base saturation

THE EFFECT of soil pH on growth of faba bean plants is shown in this comparison on an Andisol in Ecuador.

The liming approach for soils derived from volcanic ash (Andisols) is somewhat different. The high buffering capacity (resistance to pH change) of Andisols complicates lime requirement evaluation. The intensity of the buffering capacity varies from one place to another according to altitude, rainfall and temperature, which are factors that control volcanic ash weathering. For this reason, there is no simple rule to evaluate lime requirement in these soils. The use of the exchangeable Al criterion, in certain cases, underestimates lime needed, as illustrated by the data presented in **Table 4**.

Clay particles resulting from volcanic ash weathering (allophane, imogolite, humus-Al complexes, etc.) have very

TABLE 3. Liming effects on soil pH and the yield of various crops in Oxisols from Brazil.

Corn			Wheat			Soybeans		
$CaCO_3$, t/ha	Soil pH	Yield, kg/ha	$CaCO_3$, t/ha	Soil pH	Yield, kg/ha	$CaCO_3$, t/ha	Soil pH	Yield, kg/ha
0	3.9	1,150	0	4.7	1,320	0	4.6	1,943
2	4.5	4,090	3.5	5.0	2,364	3.5	4.9	2,514
4	4.7	4,420	7.0	5.2	3,031			
6	5.3	5,340						

TABLE 4. Effect of lime application on soil chemical properties and crop yield in an Andisol of the highlands of Ecuador.

Lime, t/ha	Soil pH	Ca	Mg	K cmol (+)/kg	Al	CEC	Faba beans	Barley Yield, t/ha	Oats
0	4.9	2.54	0.36	0.30	2.1	6.0	13.9	2.2	3.6
3	5.2	3.30	0.39	0.29	1.6	6.6	17.1	2.9	4.3
6	5.3	4.69	0.40	0.28	0.6	7.2	19.2	3.9	4.7
12	5.4	5.59	0.40	0.30	0.2	8.4	21.6	4.1	4.8
15	5.8	8.60	0.42	0.29	0.1	10.4	21.0	4.3	4.7

reactive surfaces. When lime is applied to these soils it reacts with the clay surfaces, creating charge (increase in CEC) while failing to increase pH or to precipitate Al. The amount of lime needed to precipitate Al varies with the age and weathering of the volcanic ash. For this reason, it is necessary to conduct simple field trails which can indicate precisely the amount of lime needed at a specific site.

Regardless of the method used to determine lime requirement in tropical soils, it is advisable to avoid excessive lime applications. Usually this happens when such soils are limed to neutrality. Tropical soils should only be limed to neutralize exchangeable Al, which generally brings soil pH to values in the 5.5 to 6.0 range. Overliming leads to soil structure deterioration, reduced boron (B), zinc (Zn) and manganese (Mn) availability, and lower yields. BC

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Dr. R.L. Yadav Receives 1995 PPIC-FAI Award for Research

The 1995 award for best research on Management and Balanced Use of Inputs in Achieving Maximum Yield went to Dr. R.L. Yadav, Project Directorate for Cropping Systems Research, Modipuram, Uttar Pradesh, India. The award is presented annually by the PPIC-India Programme and The Fertiliser Association of India (FAI).

Dr. Yadav obtained his Ph.D. degree from GBPUA&T, Pantnagar and started his research career as Sr. Scientist at IISR, Lucknow, where he worked for about 18 years. He has 276 papers to his credit and nine awards, including the FAI Silver Jubilee Award in 1988. His main research interests are integrated use of chemical fertilizers and organic manures, particularly recycling of organic farm wastes. BC

Plant and Human Nutrition

Minds are like parachutes...they only function when open.

Often, soil and plant scientists overlook the important relationship between chemical composition of plants and human nutrition and health.

But the public is aware of this. People recognize the need for potassium, phosphorus, calcium and proteins in their diet, and know that bananas and citrus are good sources of potassium.

They see the value of beta carotene and vitamins C and E, and can tell you what plants supply them. They have definite opinions about margarine produced from corn oil, or canola or sunflower oil.

Soil and plant scientists have concerned themselves with yield, pesticide resistance, weather tolerance and pollution control. Great! But do they connect soil properties and treatment with human nutrition? Are plant breeders associating plant properties with human health?

The agronomist of the future will take into account the health needs of people, which means getting adequate and balanced levels of nutrients into the plant. Soil properties, plant nutrient levels, and other plant properties will assume greater importance. What an interesting field in which to be involved.

J. Fielding Reed

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